WBS: 6.8.y.2
Level-0 MDT Trigger

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U.S. ATLAS HL-LHC NSF Conceptual Design Review
National Highway Institute - Arlington, VA
March 8-10, 2016

About the Expert

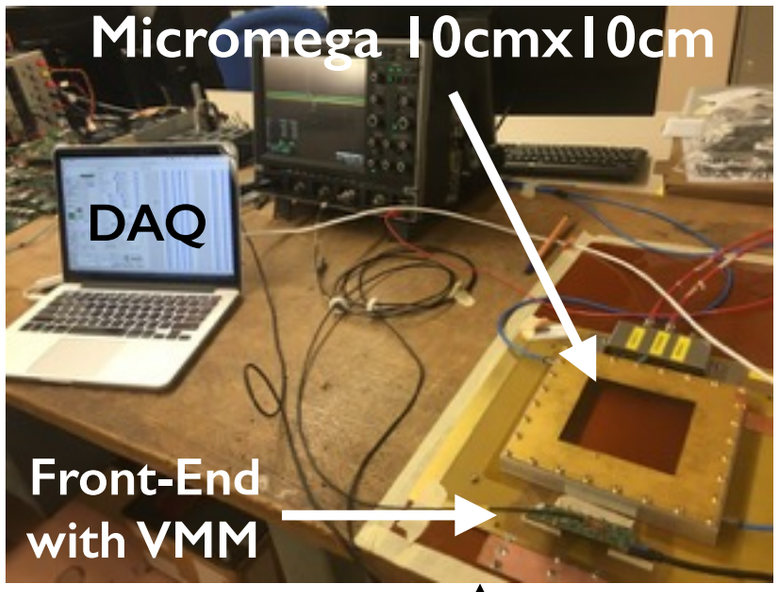
✓ Expert: Anyes Taffard, Associate Professor of Physics

✓ Institute: University of California Irvine

- ATLAS member since 2007
- Previously, CDF member (Tevatron)

✓ Experiences:

- CDF:
  - ❖ Level-1 track trigger extrapolator
  - ❖ CDF Top Properties Convener
- ATLAS Phase-I New Small Wheel muon upgrade
  - ❖ NSW TDR: Feasibility simulation studies for sTGC muon trigger
  - ❖ sTGC muon trigger simulation with ATLAS full simulation
  - ❖ NSW Readout and trigger electronics
  - ❖ Supervision of 1 postdoc and 1 graduate student contributing to NSW
- ATLAS Data Quality convener [Jan-2015-Sept 2016]
- US-ATLAS Muon R&D L2 manager for HL-LHC [March 2015-present]



About the Institution

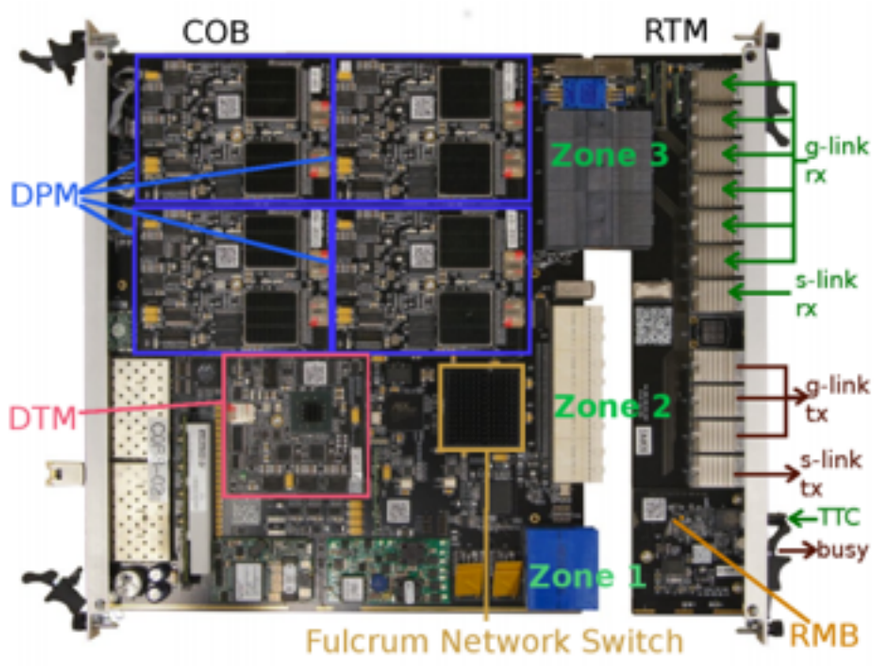
✓ Group involved in ATLAS since 1996

✓ Muon Cathode Strip Chambers: CSC (Muon Small wheel)

- CSC Readout system (ROD) and upgraded design installed in 2014 during Long-Shutdown-1
- CSC chambers installation and commissioning
- CSC maintenance, operation, performances and data quality monitoring (online & offline)

✓ Typical personnel available (off project):

- One Project Scientist
  - ❖ New hire underway
- One Software Engineer
- Two postdocs
- Two grad students
- Some undergraduate students



CSC Run-2 ROD

Outline

✓ Challenges & Motivations

✓ The solution: Level-0 MDT muon trigger

- Overview
- Functionalities
- Conceptual design

✓ R&D needed

✓ Summary

Current Muon Trigger System

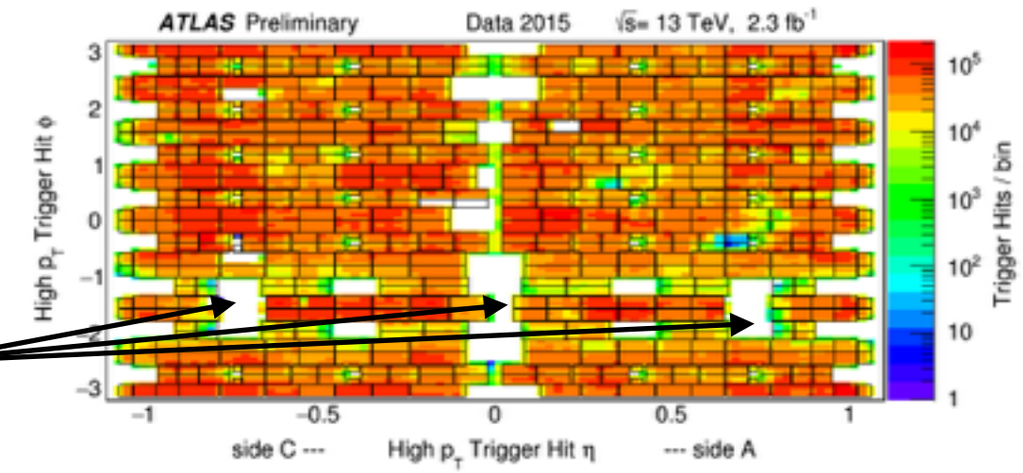
- ✓ Muon trigger provided by RPC (barrel) and TGC (endcap)
- ✓ Phase-I New Small wheel endcap $1.3<|\eta|<2.7$
  - **Will provide 2-3 reduction in single-μ trigger rate**

Limitations of current system

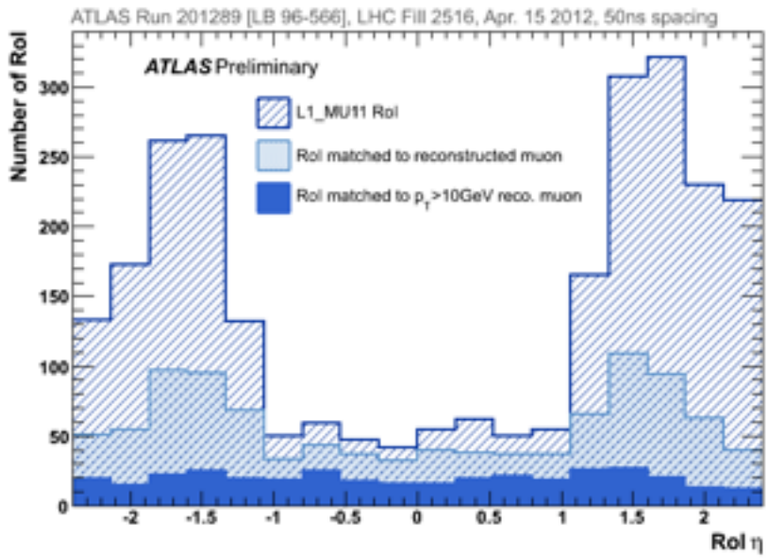
- **Moderate spacial resolution of RPC/TGC**
  - ❖ 10-20 GeV trigger rate dominated by mis-measured muon p_T or "fake" muon ($K/\pi\rightarrow\mu$)
- **Low trigger efficiency (~65% in barrel)**
  - ❖ Down by 10% for HL-LHC since RPCs need to be operated at a reduced voltage to mitigate aging
- **Reduced acceptance in barrel RPC**
  - ❖ Address in HL-LHC by adding RPC chambers

RPC trigger coverage

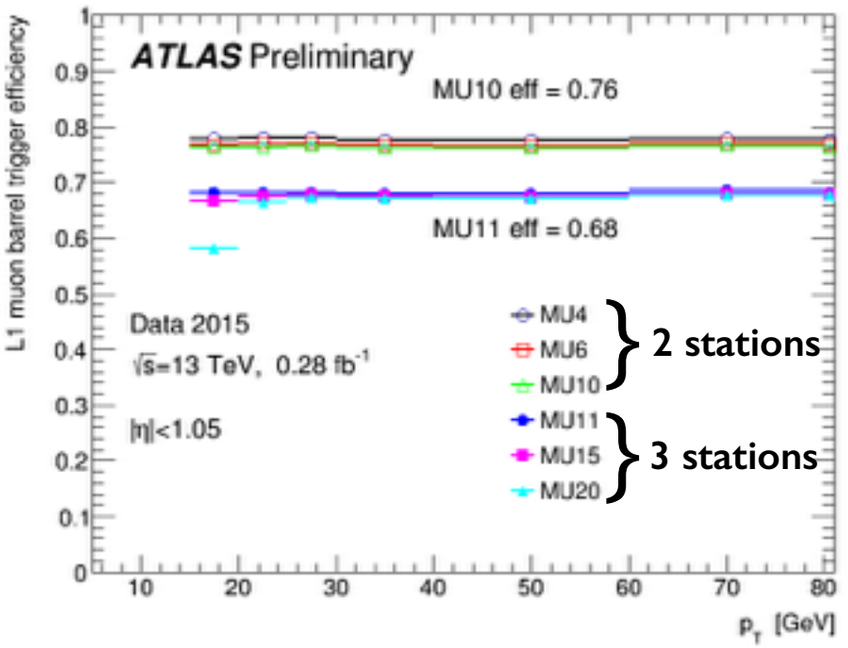
Detector feet



Level-1 Muon Trigger Composition

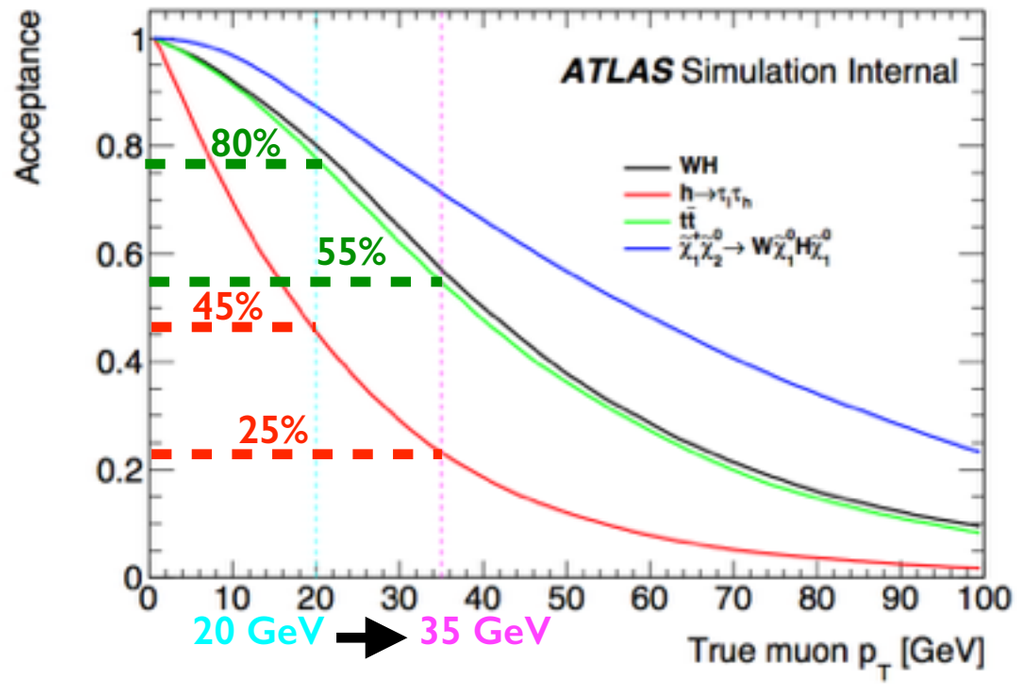


RPC trigger efficiency
for reconstructed muon p_T>15GeV

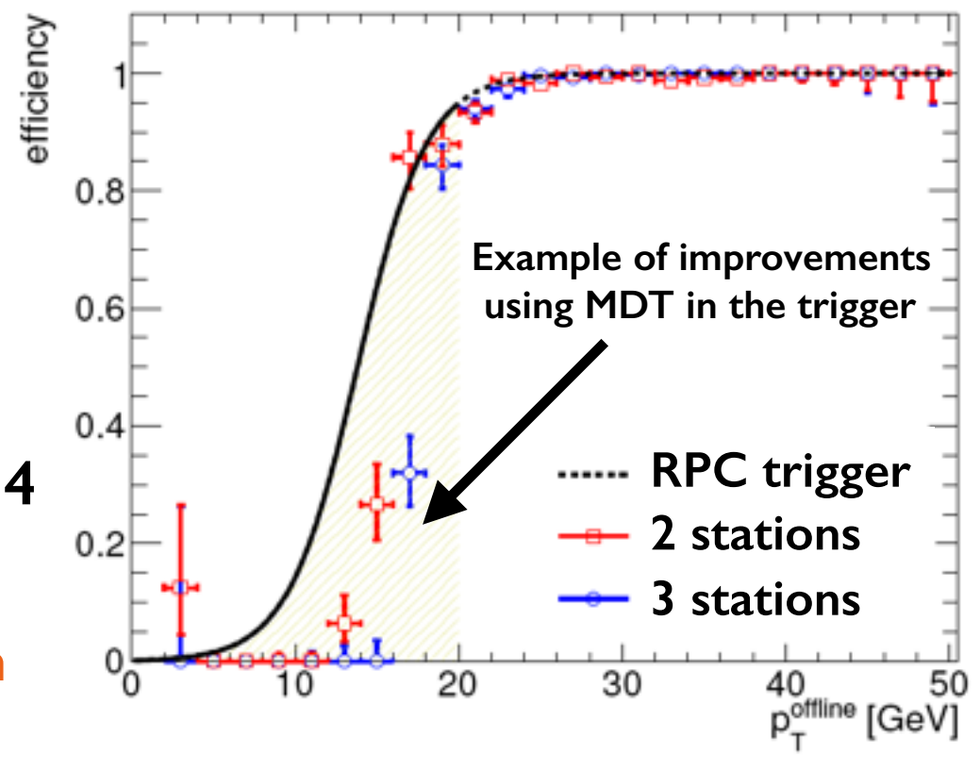


Motivations to Muon Trigger Upgrade

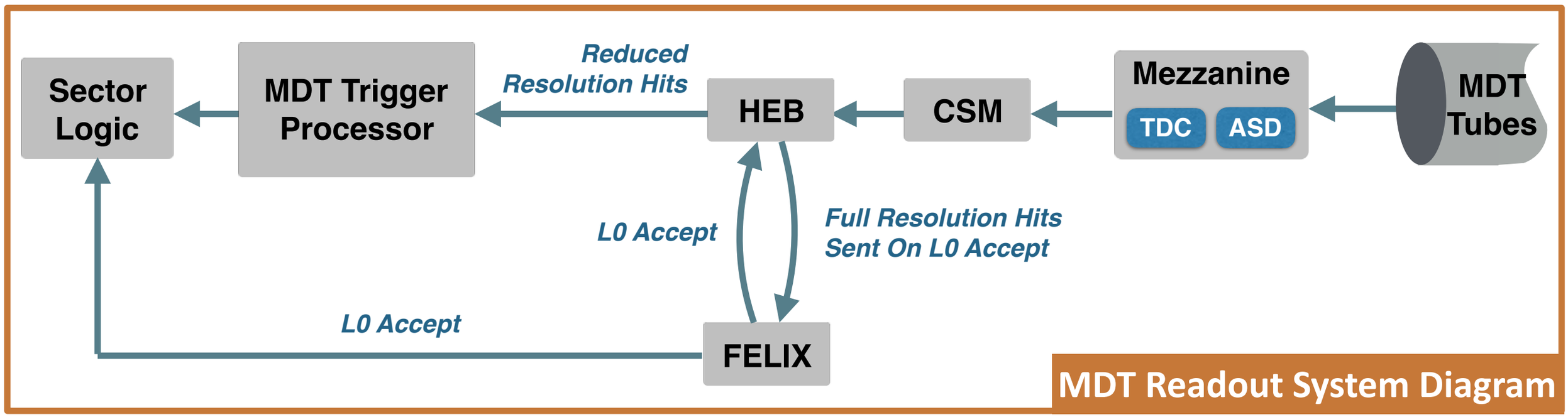
- ✓ HL-LHC physics program necessitates maintaining single μ trigger p_T threshold of ~20 GeV
- ✓ With current system and with HL-LHC conditions, the single μ trigger rate for p_T>20GeV would increase by a factor 2
  - To maintain the current trigger rate, the p_T threshold would need to be increased to 35 GeV
  - Such p_T threshold would significantly degrade the physics performance.



- ✓ Solution: Sharpen muon p_T threshold
  - By using MDT precision hits, muon p_T can be measured more accurately at level-0
  - Reduces fake muon trigger rate by up to a factor 4
  - Add redundancy to triggers based on RPC/TGC
    - ❖ Less stringent requirements imply improvement in trigger efficiency



Overview of Muon Trigger Upgrade



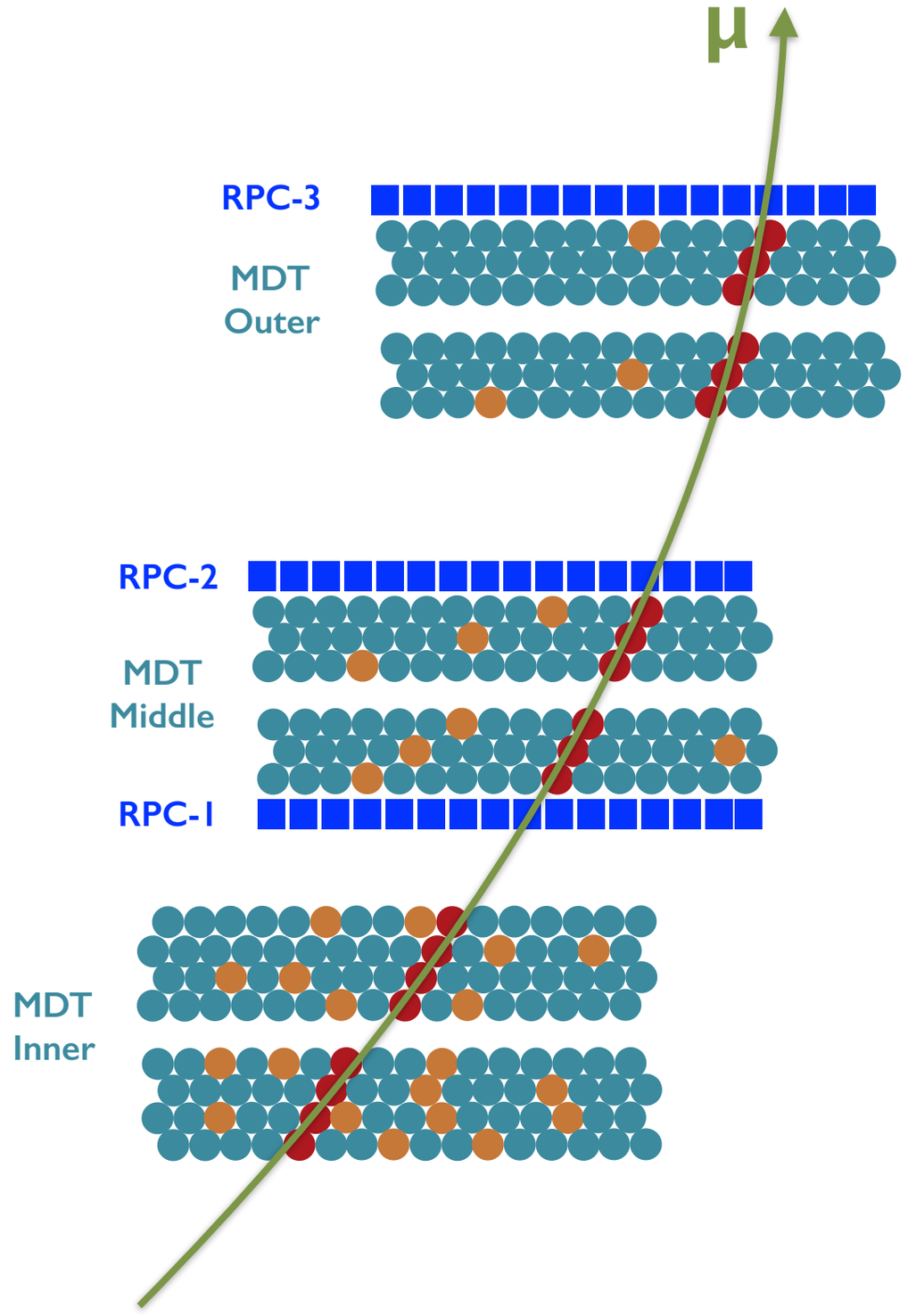
- ✓ To handle increase in rates and fakes associated with HL-LHC conditions, MDT readout electronics needs to be upgraded
- ✓ Offers the opportunity to implement an MDT based Level-0 muon trigger

- ✓ Level-0 MDT trigger is one of the critical component necessary to maintain the muon trigger performances necessary for the HL-LHC physics program
- ✓ This project is synergetic with NSF US-ATLAS plans in the muon upgrade for HL-LHC
  - **UCI well position based on past/current experience in muon readout and trigger system**

System Requirements

✓ Goals:

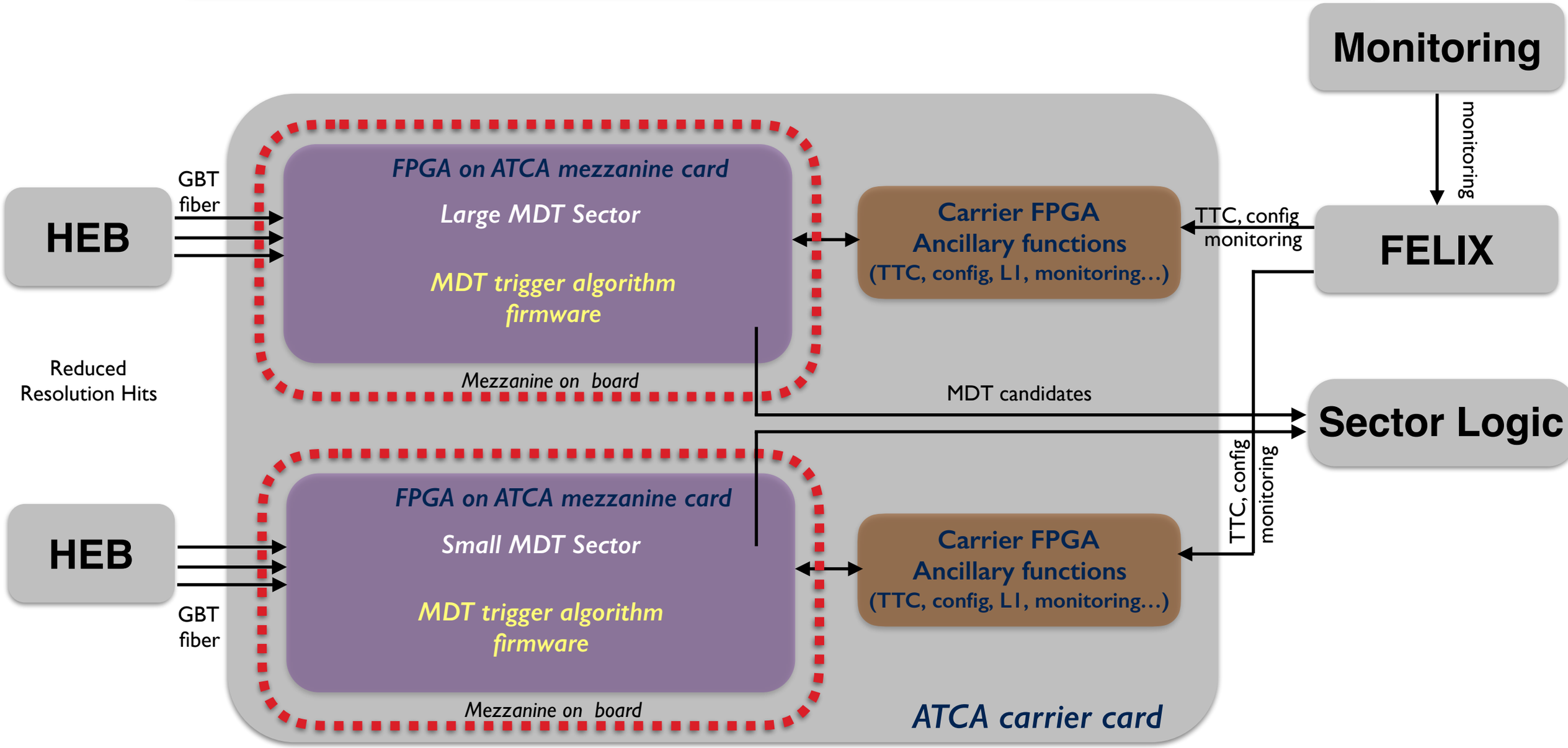
- **Use MDT and sMDT precision hits to preform a Level-0 muon trigger decision within 6μs latency**



✓ Functionalities

- **Calibrate MDT hits drift time**
- **Segment finding on each MDT layer**
- **Segments linking**
- **Track fitting**

Conceptual Design



✓ **Deliverables: Design, production and testing of**

- **Mezzanine board**
- **Firmware for MDT trigger algorithm**

R&D Effort Toward TDR

TDAQ TDR: End-2017
Muon TDR: Mid-2017

✓ What are the major challenges remaining?

- **Latency budget**
  - ❖ Preliminary studies show that an MDT trigger algorithm can be performed within 4.5μs (with 1.6μs used to received hits from CSM to MDT trigger)
  - ❖ Latency depends on algorithm implementation choices

✓ What R&D needs to be done to address these challenges

- **Develop an MDT based trigger algorithm that can meet the stringent latency budget.**
  - ❖ Define specifications, functionalities and performance goals
  - ❖ Implement preliminary algorithm on a demonstrator board to estimate its latency.
  - ❖ Estimate the full data chain latency

R&D effort (cont.)

Planned activities and milestones beyond TDR:

✓ FY18:

- **Refine trigger algorithm and estimate performance**
- **Define hardware choice**
  - ❖ Start design and simulation of firmware

✓ FY19:

- **Finalize firmware design, simulation and implementation on evaluation board to test performances**
- **Start design and simulation of mezzanine board**

✓ FY20:

- **Begin full prototype design of mezzanine board and firmware**

Summary

- ✓ Level-0 MDT trigger is one of the critical component to maintain the muon trigger performances necessary for the HL-LHC physics program

- ✓ Project is synergetic with the rest of NSF US-ATLAS muon upgrade

- ✓ Effort built on group expertise and experience

- ✓ Clear R&D path toward TDR and beyond to insure readiness for construction phase

BACKUP

Cost Estimate

✓ Cost was estimated based on the experience from the New Small Wheel (NSW) trigger processor, which is a comparable system with AMC fitted with FPGA within an ATCA carrier card (see p5 of BoE)

- Cost driven by FPGA
  - ❖ For the estimate used Xilink Virtex-7 FPGA (same as for NSW)

Element TDAQ	Quantities	Unit Cost	Cost [$ 2015]
ATCA board base for MDT trigger processor			**12,717**
FPGA segment finding, linking & track fitting	2	4,674	9,348
PCB	2	1,087	2,174
PCB assembly	2	326	652
PCB misc parts	2	272	543

Table 2: Cost estimate for the MDT trigger AMC

- 32 production boards
- 4 additional boards for testing and verifications
- 2 prototypes
  (see p2 of BoE)

6.8.y.2 MDT Trigger						
WBS	Description	Labor FTE	Labor Ayk$	M&S Ayk$	Travel Ayk$	TOTAL Ayk$
6.8.y.2	MDT Trigger	11.81	1,610	597	49	2,256
	Engineers	5.06				
	Techs	2.50				
	Students	4.25				

Table 1: The deliverables from UC Irvine

Risk Estimate

✓ Schedule Risk

- **R&D does not yield sufficient information to define completely specifications for mezzanine board and/or firmware**
- **Mitigate risk by ensuring that relevant informations are available to define them. Ensure that there is viable path for communication between boards and all is accounted for in latency calculation.**

✓ Cost Risk

- **Final FPGA cost may be higher than anticipated.**
- **Mitigate risk by performing studies leading to the best hardware solution both in term of performance and cost.**

✓ Scope Risk

- **ATCA carrier cards fairly new system to ATLAS**
- **Mitigate risk by working with collaborators experience with such systems**

✓ External Risk

- **ATCA carrier card developed by external collaborators. Delay in delivery will reduce testing time of final integrated design**
- **Mitigate risk by developing standalone testing stands. Modest delay can be accommodated within current schedule**

See BoE p4-5